§5. Intermittent Bursts of Turbulence Correlated with Loss of Density Gradient in High Density LHD Plasmas

Michael, C.A., Tanaka, K.,
Vyacheslavov, L.N., Sanin, A. (Budker Institute of Nuclear Physics),
Sakamoto, R., Kawahata, K.

Recently, pellet-fuelled high density plasmas were achieved with central density approaching $10^{21}m^{-3}$. These plasmas are characterized a high density core with a "diffusion barrier" around mid radius, correlating with the position of zero magnetic shear [1]. Since beta gradients in the diffusion barrier region are very high, pressure driven interchange/ballooning mode turbulence is expected to be excited and may limit the operation of high density scenarios.

Ion gyro-scale turbulence (k=2-10mm^{-1}) can be measured along a line of sight at R=3.75m with the CO_2 laser phase contrast imaging (PCI) system [2,3]. Also, the detailed spatial structure and temporal dynamics of the density profile in high density plasmas can be diagnosed with find spatial resolution (7mm) using an imaging heterodyne interferometer from the same CO_2 laser [3,4]. The density profile in one such high density discharge is plotted 0.2s after the last pellet injection in Fig. (1). The points denote the spatial resolution after Abel inversion. The density gradient is much stronger for ρ<0.5 suggesting reduced diffusion in this region. In Fig (2), the temporal dynamics relative to the last pellet injection (time t_0) of (a) fluctuation level at ρ=0.7, (b) normalized density gradient at ρ=0.6 (at the foot point of the diffusion barrier) and (c) the normalized temperature gradient is plotted for the same discharge. These locations were chosen based on the availability of fluctuation data according to the sight line of the PCI system. The missing fluctuation data in (a) for t=0.23-0.35s is because of large Shafranov shift.

Fluctuations have an intermitted burst-like temporal character. These bursts are not correlated with the pellet fuelling and so indicate that an explosive instability is excited, in a similar manner to ELMs in Tokamaks. To understand the origin of the burst-like behaviour and the driving terms for fluctuations, they must be compared with normalized density and temperature gradients. It is clear from Fig. (2b) that, the negative normalized density gradient increases in time after pellet ablation (profile becomes more peaked). However, there are distinct drops in the density gradient at particular times (indicated by vertical dashed lines) that correlate well with the bursts of fluctuations. Moreover, they all appear to occur at a similar threshold of $-a/L_n\sim4$. This suggests that the instabilities may be pressure driven by the steep density gradient, as expected theoretically for ballooning and interchange instabilities. However, after the last burst at $t-t_0$=0.17s, the negative density gradient continues to increase. This suggests that another transport/turbulence relevant parameter has changed (for example, flow shear). Examining Fig (2c), the negative normalized electron temperature gradient (measured using the YAG Thomson scattering system) is larger at the last fluctuation burst $t-t_0$=0.17s than beforehand (i.e, the profile is more peaked). This is suggestive that the peakedness of the temperature profile may be a direct or indirect parameter controlling the stability of the high density plasmas.

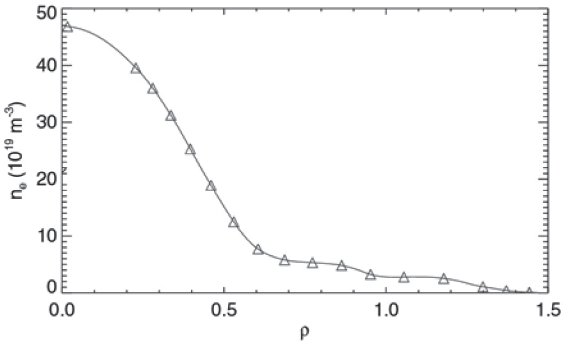

Figure 1: Density profiles for #68596 (R_{ax}=3.75m) at $t-t_0$=0.2s from CO_2 interferometer

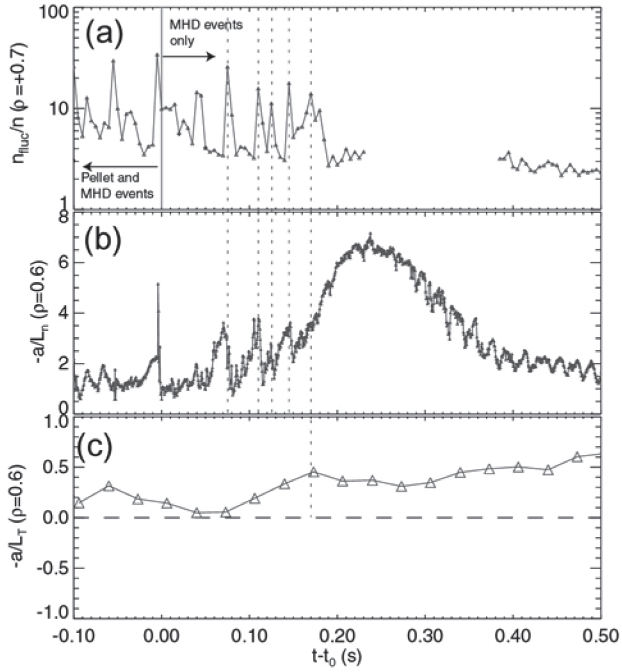

Figure 2: Time evolution of (b) fluctuation level at ρ=0.7, (c) negative normalized density gradient at ρ=0.6 and (d) negative normalized temperature gradient at ρ=0.6 for #68596 (R_{ax}=3.75m)

[1] N. Ohyabu et al. Phys Rev Lett 97, 055002/1 (2006)
[2] A.L. Sanin et al. Rev. Sci. Instrum. 75, 3439 (2004)
[3] C.Michael et al., Rev. Sci. Instrum. **77**, 10E923 (2006)
[4] K.Tanaka et al., Plasma and Fusion Research Volume 2, S1033, (2007)